THE PETROGRAPHICAL PROVINCE OF ESSEX COUNTY, MASS. IV.

BASIC DIKES

By far the greater part of the dikes of this region are dense black rocks, evidently very basic in character. The majority of these are diabases of various kinds, only a few not belonging to this ever-present family and representing more unusual types. However, these basic dikes have been so far but little investigated, but it will not be amiss to describe the specimens in my possession.

Camptonitic dikes.— Cutting the foyaite of Salem Neck and, according to Sears, the "augite-syenite" of Coney Island in Salem Harbor are dikes of dense, black, finely crystalline rock without phenocrysts, and composed essentially of hornblende, less augite, and plagioclase. These rocks are unlike typical camptonites since there are no large and abundant ferromagnesian phenocrysts, and alumina is rather high. In certain respects they seem to be allied to the proterobases. They are provisionally classed with the camptonites for various reasons, among which may be mentioned their connection with foyaite, certain features of their chemical and mineralogical composition, and their resemblance to camptonitic rocks from localities in Maine, New Hampshire, Vermont, and Norway. It is, by the way, a somewhat remarkable fact that no typical camptonites or monchiquites have yet been observed in the region.

Under the microscope these rocks are holocrystalline, and in fresh specimens have a structure approaching the ophitic, though the colored components are, as a rule, more automorphic than is the case when this structure is typically developed. The following minerals are present: much hornblende, less pyroxene, occasional olivine, plagioclase, a little orthoclase, some magnetite, and rare apatite. Neither biotite nor titanite were seen.

The hornblende forms either stout prismatic crystals or irregular grains. In the latter case it is generally, but not constantly, later than the plagioclase and interstitial to some extent. It is a peculiar yellow-brown, closely similar to the barkevikite of the Norway rocks, as shown by comparison with sections of these. The pleochroism is strong: for the axis nearest *c*, dark yellow-brown; parallel to axis *b*, about the same, nearly parallel to axis *a*, light greenish-yellow. The depth of the color rendered the determination of the axes of elasticity uncertain. The extinction is rather high, about 20 degrees. This hornblende frequently occurs as a primary border about augite and magnetite, as in the hyperitic diorites. The pyroxene, which forms irregular grains or occasionally large porphyritic crystals, is colorless, with sometimes a tinge of green or violet. Olivine is rare, except in one specimen from Coney Island, in large corroded colorless grains. They are usually altered at the borders to a black granular substance, and are occasionally serpentinized. The plagioclase, which occurs in long lath-shaped sections, tabular parallel to *b* (010), as well as in anhedra, is highly twinned. Measurements by Michel-Lévy's method indicate a labradorite with the composition Ab_3 An_4, though some are nearer the andesines. Small colorless interstitial grains with low refractive index are referred to orthoclase.

	I	II	III	IV
SiO_2	46.59	48.98	45.20	48.08
TiO_2	1.41	0.56	0.68	2.57
Al_2O_3	17.55	17.76	17.12	16.95
Fe_2O_3	1.68	2.14	5.98	4.78
FeO	10.46	6.52	6.55	7.60
MnO	.....	.....	.....	trace
MgO	7.76	2.09	5.29	5.51
CaO	10.64	8.36	7.89	7.79
Na_2O	3.31	6.77	4.23	3.37
K_2O	0.72	2.08	2.31	1.42
H_2O (110°)	0.10	.....	.....	.....
H_2O (ignit.)	0.07	4.50	5.35	0.80
P_2O_5	.....	.....	.....	0.63
CO_2	....	0.82	.....	.....
	100.29	100.58	100.60	99.48

I. Camptonite (?). Salem Neck. H. S. Washington anal.

II. "Diorite-Porphyrite." St. Johns, N. B. W. D. Matthew, Trans. N. Y. Acad. Sci., Vol. XIV, p. 213, 1895.

III. Camptonite. Portland, Me. E. C. E. Lord, Amer. Geol., Vol. XXII, p. 344, 1898.

IV. Bronzite-Kersantite. Hovland, Norway. Brögger, op. cit., Vol. III, p. 75.

An analysis of a fresh specimen from a narrow dike cutting foyaite on Salem Neck is given in I. The low titanium oxide accords with the absence of titanite and the character of the pyroxene. It is evident that alumina largely replaces ferric oxide in the ferro-magnesian minerals. This is a feature of barkevikite as shown by Flink's analysis,[1] and some of the hornblendes whose composition has been calculated by Brögger,[2] as well as of the hornblende of Hawes's camptonite.[3]

As was stated above very similar rocks have been observed in New England. For instance, it resembles a specimen from Livermore Falls, near Campton, N. H., for which I am indebted to Professor Pirsson. This, however, does not carry hornblende phenocrysts, and is also like some of the camptonites of Lake Champlain.[4] Hobbs[5] also describes similar rocks as augite-diorite, occurring in connection with the diabase of Medford, Mass. A nearly identical rock is described by W. D. Matthew[6] as occurring in dikes near St. Johns, N. B. The hornblende is also apparently barkevikite, and an analysis of this rock is given in II. Very recently E. C. E. Lord[7] has described a dike of camptonite from Portland, Me., which is closely allied, and the analysis of which is given in III. These two contain considerably more alkalies than those described in this paper. These

[1] DANA, A System of Mineralogy, New York, 1892, p. 403.

[2] BRÖGGER, op. cit., III, p. 110.

[3] LORD, Amer. Geol., Vol. XXII, p. 343, 1898; also, ROSENBUSCH, Elem. Gesteinlehre, p. 234, No. 1, 1898.

[4] KEMP and MARSTERS, Bull. U. S. G. S., No. 107, p. 29, 1893.

[5] W. H. HOBBS, Bull. Mus. Comp. Zoöl., Vol. XVI, p. 10, 1888.

[6] W. D. MATTHEW, Trans. N. Y. Acad. Sci., Vol. XIV, p. 210, 1895.

[7] E. C. E. LORD, Amer. Geol., Vol. XXII, p. 342, 1898. *Cf.* KEMP, dikes near Kennebunkport, Me., Amer. Geol., p. 129, 1890.

are all decidedly more acid than the usual camptonites, and carry higher alumina. Chemically they show marked affinity with certain kersantites from Norway described by Brögger,[1] one of his analyses being given in IV.

Vogesitic dikes.—A few dikes were found of a dark rock composed of hornblende, augite, and biotite, but with alkali-feldspar very largely predominating over plagioclase. A little quartz is also apt to be present, which is apparently primary. These rocks then have the mineralogical composition of vogesite or minette, apart from the presence of quartz, and are provisionally put here, since no chemical analysis has yet been made of them.

As an example there may described a dike from Davis Neck, Cape Ann, which is almost black, fine-grained, and compact, and with small shining black phenocrysts of ferro-magnesian minerals. Of these the pyroxene is colorless or very pale green, the hornblende of a light bluish-green, both in irregular grains, and the biotite in thick plates of a light brown color and highly pleochroic. These minerals are not distributed evenly, but occur in streaks in which one or the other predominates. The interstitial groundmass is of colorless granular alkali-feldspar without plagioclase or quartz. A little magnetite is present but no apatite.

Diabase.—Dikes of dense black rock, which may be grouped under this heading, are very abundant. They far outnumber all the other dikes put together, but as is usually the case they are rather monotonous in character, as well as nearly always more or less altered. Shaler's map of Cape Ann will show their abundance, and to his paper[2] the reader is referred for a full discussion of their occurrence, dip and strike, and other features. As regards their relations to the other rocks it may be noted that they cut, and are hence later than, all the other types.

They vary from fine-grained to aphanitic, the usual change in texture from center to border being often seen. In general they are not as coarse-grained as the sheets, dikes, and flows of

[1] BRÖGGER, op. cit., Vol. III, p. 71

[2] SHALER, Ninth Ann. Rep. U. S. G. S., 1889.

similar rock which are met with in such abundance in the Triassic of Connecticut and New Jersey, this being due to their having cooled as much smaller bodies. Amygdaloidal structure is very rare. They may be divided roughly into two main groups, the ophitic and basaltic, though these merge into each other, and frequently the center of a dike is ophitic while its border is basaltic.

The ophitic diabases present the usual features. The feldspar, in stout plates, is chiefly a well-twinned plagioclase, with extinction angles corresponding to a labradorite of about the composition $Ab_1\ An_3$. It is often cloudy or epidotized through alteration. A little orthoclase seems to be present. The augite, which is seldom automorphic, is pale violet-gray in thin sections, and is frequently uralitized, often to such an extent that little of the original mineral remains. Magnetite is quite common in large grains, often showing octahedral outlines, and has a strong tendency to stout skeleton growths. An interesting case of this is seen in a dike-cutting rhyolite on Marblehead Neck where the magnetite skeletons assume the form of small stout crosses with thickened ends, or with their ends joined by the sides of a hollow square, the cross in this case forming the diagonals. These growths are analogous to those of leucite in certain leucitites from Montana[1] and Italy.[2] The magnetites are frequently accompanied or surrounded by brown, apparently secondary, biotite, even in the freshest specimens. With this exception neither biotite nor hornblende is to be seen, nor was olivine observed. Apatite is not abundant.

The basaltic diabases are black and aphanitic, without megascopic phenocrysts. They show in thin sections laths of clear labradorite and some crystals of augite in a mixture of augite grains, small labradorite laths and magnetite with considerable light-brown glass base. The magnetite very frequently assumes delicate arborescent forms, branching at right angles, which are very pretty and characteristic. In a small apophysis of the

[1] L. V. PIRSSON, Bearpaw Mountains, Am. Jour. Sci. (4), Vol. II, p. 145, 1896.

[2] H. S. WASHINGTON, Bolsena, JOUR. GEOL., Vol. IV, p. 557, 1896.

ophitic Dike 73, at Bemo's Ledge, Cape Ann, magnetite is wanting and the brown glass abundant. Flow structure is sometimes seen. These varieties closely resemble many normal olivine-free basalts.

	I	II	III	IV	V
SiO_2	47.12	48.75	51.78	51.36	36.85
TiO_2	3.27	0.99	1.41	....	....
Al_2O_3	14.43	17.97	12.79	16.25	15.46
Fe_2O_3	3.33	0.41	3.59	2.14	....
FeO	11.71	13.62	8.25	8.24	17.50
MnO	....	0.91	0.44	0.09	....
MgO	6.05	3.39	7.63	7.97	5.60
CaO	9.63	8.82	10.70	10.27	15.73
Na_2O	2.58	1.63	2.14	1.54	....
K_2O	1.11	2.40	0.39	1.06	....
H_2O (110°)	0.28	....	....	....	....
H_2O (ignit.)	0.34	0.60	0.63	1.33	....
P_2O_5	....	0.68	0.14	....	....
	99.85	100.17	99.89	100.28	91.14

I. Diabase. Rockport. H. S. Washington anal.

II. Diabase. Medford, Mass. Sweetser anal. Traces of CO_2 and FeS_2. Probably Al_2O_3 too high and MgO too low. Hobbs, Bull. Mus. Comp. Zoöl. XVI, p. 9, 1888.

III. Diabase. West Rock, New Haven, Conn. G. W. Hawes anal. Proc. U. S. Nat. Mus., IV, p. 132, 1882.

IV. Diabase. Watchung Mountain, Orange, N. J. L. G. Eakins anal. Bull. 148 U. S. Geol. Surv., p. 80, 1897.

V. Diabase (?). Marblehead Neck. R. Pearce, Proc. Colo. Sci. Soc., IV, 1893.

For purposes of analysis the freshest specimen was chosen from a dike of ophitic diabase cutting the granite in the large quarry pit at Rockport. It calls for little remark, except that the alumina is rather low and the titanium oxide is high. It resembles analyses of other diabases from Massachusetts, one of which is given (II), but is more basic than the "traps" of Connecticut and New Jersey (III and IV). For purposes of completeness a partial analysis is given (V) of a so-called diabase dike, briefly noticed by R. Pearce, from Marblehead Neck. It is not very satisfactory. The silica is abnormally low, lime high,

as well as iron oxides, and the large loss is difficult to account for, assuming that the analysis is correct. There cannot be enough alkalies to make up the deficiency, and it is probably largely water. The rock is possibly decomposed, since Merrill[1] has shown that diabase loses silica through decomposition. It is also possible that it is a monchiquite.

Labradorite-porphyry.—Closely related to the diabases are a few dikes distinguished by the presence of prominent phenocrysts of plagioclase in a black, fine-grained groundmass. The best example is Shaler's Dike 175, which cuts across the quarry pit at Pigeon Cove. It is eighteen feet in width, with a strike of N. 9° W.[2] The phenocrysts here are very large and automorphic. A similar dike cuts the tinguaite at Pickard's Point, in which the phenocrysts at the center are even larger, attaining diameters of more than six inches; toward the borders they are smaller, and at the contact very small.

The groundmass of these rocks is like that of the diabases, though an ophitic structure is less often developed. It is composed of labradorite, augite, and magnetite, primarily, but in every case is more or less altered, so that secondary hornblende and biotite with chlorite, etc., are present in abundance, and any analysis would be unsatisfactory.

EXTRUSIVE ROCKS

Rhyolite.—The only flow rocks found in Essex county are rhyolites, which occur in large sheets about Lynn, Newbury, Old Town, and Marblehead Neck. The last is the only locality which I have visited. This is not the place to dwell upon the discussions which have taken place as to the origin of these rocks, between Sterry Hunt and his followers, who tried to show that these, as well as all the igneous rocks of the region, were altered sediments, and the other party, headed by Wadsworth and Diller, who finally overthrew this view and proved conclusively that they are typical volcanic flows. For particulars of this discus-

[1] G. P. MERRILL, Bull. Am. Geol. Soc., Vol. VII, p. 349, 1896.

[2] SHALER, op. cit., pp. 592, 607.

sion the reader is referred to "The Azoic System," by Whitney and Wadsworth.[1]

These rhyolites are dense, black, aphanitic rocks, with a dull or subvitreous luster and subconchoidal to even fracture. Small, white feldspar phenocrysts are scattered through this black groundmass. A banded or flow-structure is often noticeable, and is especially well brought out on weathered surfaces.

Under the microscope these rocks present a somewhat monotonous appearance. The feldspar phenocrysts are usually quite sharply automorphic, less often fragmentary. Most of these are of orthoclase, or rather soda-orthoclase, while a few show the twinning lamellæ and extinction angles of oligoclase-albite. They are all somewhat decomposed so that optical examination is unsatisfactory.

The groundmass is composed of alkali-feldspar with some finely granular quartz, very small shreds and grains of pale greenish pyroxene and a little magnetite. Glass is present in some specimens, but in the majority of cases it has been devitrified, and its former presence is difficult to determine with certainty. Some of the specimens were apparently primarily holocrystalline. Flow-structure is observed, but is not as marked as one would be led to expect from some of the weathered specimens. These rhyolites, it may be added, are accompanied by ash beds and breccias.

I owe to Mr. Sears a specimen of a dike rock much like these rhyolites, which cuts the diorite on the south shore of Salem harbor, west of Marblehead. It shows flesh-colored feldspar and colorless quartz phenocrysts in an aphanitic groundmass. In thin section it resembles the rhyolites, but is distinguished by the abundance and sharp outlines of the quartz phenocrysts and the presence of numerous spherulites in the devitrified groundmass, which exhibit a black cross between crossed nicols.

[1] Bull. Mus. Comp. Zoöl., Vol. VII, Cambridge, 1884, pp. 331–565. *Cf.* also G. H. WILLIAMS, JOUR. GEOL., Vol. II, p. 24, 1894.

SiO_2	70.64	MgO	0.52
TiO_2	0.90	CaO	1.24
Al_2O_3	15.34	Na_2O	5.23
Fe_2O_3	1.83	K_2O	3.55
FeO	1.10	H_2O (110°)	0.14
MnO	trace	H_2O (ignit.)	0.38
			100.87

Rhyolite. Northeast coast of Marblehead Neck. H. S. Washington anal.

For the analysis a typical specimen was chosen from the northeast coast of Marblehead Neck. As will be seen, these rocks are rather acid, and resemble the quartz-syenite-porphyry more than they do the aplite. The only point to be mentioned here is that soda is considerably higher than potash.

Keratophyr.—The last rock to be described is that by which this region is, perhaps, best known, which Rosenbusch[1] has taken as the type of his bostonites, and which Sears[2] has described as keratophyre. Accepting provisionally Rosenbusch's system of classification the choice of names depends on whether the rock occurs as a dike or a flow. Owing partly to the fact that the exposure is only visible at low tide the relations are somewhat difficult to make out. My observations were confirmatory of the views expressed by Wadsworth[3] and Sears[4] that the rock forms a flow and not a dike, overlying rhyolite and conglomerates. This being so, I think that the name bostonite is not justified in this case, and I prefer to retain Sear's name, keratophyr (rather than trachyte), on account of the large content of anorthoclase, even though this name is in several respects a very bad one.

My specimens come from Boden's Point, below Mr. Foster's house, and from below the Corinthian Yacht Club House. Although the rock has been described by Sears and Rosenbusch, a few words may be devoted to it. The freshest specimens are

[1] ROSENBUSCH, Tsch. Min. Pet. Mitth., Vol. XI, p. 447, 1890; Mikr. Phys., Vol. II, p. 467, 1896.

[2] SEARS, Bull. Mus., Comp. Zoöl., Vol. XVI. p. 167, 1890.

[3] WADSWORTH, Proc. Boston Soc. Nat. Hist., Vol. XXI, p. 288, 1881.

[4] SEARS, op. cit.

creamy white, weathering to brown, very fine-grained and with a dull luster, and a tendency to schistosity, which largely accounts for the earlier view that this was a sandstone. A few glistening white phenocrysts of anorthoclase are visible.

In thin section the phenocrysts show the characters described by Rosenbusch and Sears. The groundmass is trachytic with pronounced flow-structure, and is composed largely of small alkali-feldspar laths, these being generally clear. The interstitial matter is clear and colorless with low refractive index, partly isotropic and partly feebly doubly refracting. Some of it seems to be glass and some kaolinized feldspar. There is considerable "dust" and many small black and brown specks, the remains of former ferro-magnesian minerals, which, however, never were present in a large amount. Very few traces of these remain, only rare, small biotite flakes being seen. A little quartz is present, but is rare.

Two analyses of this keratophyr are given, one by myself and the other by Dr. Chatard, of the United States Geological Survey, for Mr. Sears. They resemble each other very well, though mine shows a little more silica. It will be noticed that they are not markedly different from the rhyolite, though in this lime is higher.

	I	II
SiO_2	71.40	70.23
TiO_2	....	0.03
Al_2O_3	14.76	15.00
Fe_2O_3	1.68	1.99
FeO	0.72	....
MnO	trace	0.24
MgO	0.55	0.38
CaO	0.10	0.33
Na_2O	4.79	4.98
K_2O	5.16	4.99
H_2O (110°)	....	0.91
H_2O (ignit.)	1.46	1.28
P_2O_5	....	0.06
	100.62	100.42

I. Keratophyr. Boden's Point, Marblehead Neck. H. S. Washington anal.
II. Keratophyr. Boden's Point, Marblehead Neck. T. Chatard anal. Sears, Bull. Mus. Comp. Zoöl., XVI, p. 170, 1890; also Bull. 148, U. S. Geol. Surv., p. 78, 1897.

HENRY S. WASHINGTON.